Risk Analysis of Potential Control Options for the 1997 Nonpathogenic Avian Influenza Outbreak in Pennsylvania

September 11, 1997

BACKGROUND

Pennsylvania is currently dealing with an outbreak of nonpathogenic avian influenza (H7N2) in commercial egg layer flocks. At this point Pennsylvania has identified over a dozen infected flocks in the Lancaster County area. In July 1997, the Veterinary Services management and the Pennsylvania Department of Agriculture (PDA) requested an analysis of potential control options.

The objective of this report is to provide decision makers with information regarding the relative consequences and costs of various control options. This analysis may be useful in framing the problem and for suggesting areas for further exploration. In the short time frame for this analysis, we consulted with the poultry industry, poultry researchers, and the Economic Research Service to obtain best available data. The results in this report apply to the situation as of August 1997.

METHODS

We used a state-transition disease model and economic welfare analysis to simulate the results of four different control options. These options are: 1) voluntary controls "do nothing", 2) depopulation-repopulation, 3) quarantine and containment, and 4) vaccination with quarantine. Also, we modeled several regionalization/export restriction scenarios. Brief descriptions of the models are presented below. A more complete description is provided in the "Baseline Analysis System Technical Documentation" (Ken Forsythe, draft manuscript, 1997).

Disease Spread Model

The disease-spread model is an application of state-transition analysis. State-transition analysis involves defining mutually exclusive categories ("states") into which animals, herds, flocks, plants, can be divided. We used a basic three state infection model: susceptible, infectious, recovered or immune. In this analysis the flock was the basic unit of concern. For purposes of the simulation, flocks in the susceptible state were defined as normal, healthy and available to be infected with avian influenza. Flocks in the infectious state have avian influenza virus circulating, among birds, and are capable of infecting other flocks. After a flock is infected it will be immune to re-infection or removed by depopulation depending on the scenario being modeled. If repopulated, these flocks will return to the susceptible state.

Pathways ("transitions") between the states must also be defined. Pathways are represented mathematically as the probability of moving from one state to another. States and pathways serve as the basis for a series of simulations. These simulations project the spread of a disease or pest over time in hypothetical epidemics. They can be used to compare the relative value of different scenarios.

Information generated from the disease-spread model is combined with physical impact data such as death or production losses. The resulting output gives an estimate of the biological consequences associated with the disease's spread. The economic model then uses the calculated biological consequences as input in estimating the monetary impact on producers and consumers.

For this analysis, the area of risk was defined as all Pennsylvania counties affected by the final Federal quarantine in 1984. According to the 1982 census, 468 layer premises (>3,200 birds) were in this area. The model used this number, 468, as the starting number of susceptible flocks. Each hypothetical flock consisted of 70,000 egg laying chickens. Each egg layer was assumed to produce 270 eggs per year (Pennsylvania Agriculture State Statistics, 1996).

Flocks move from susceptible to infected to immune and back to susceptible status based on incidence rates, proportion of flocks becoming immune, proportion of susceptible flocks vaccinated, and depopulation to repopulation rates. These proportions were derived by estimating the average waiting time a flock or premises would spend in the infectious or immune states under various control options. Time in infectious state was defined as the time that a flock would be infected with the virus before it was diagnosed and an action was taken to isolate the flock. Time in immune state is defined as the time a premises is either vacant or the birds on the premises are no longer susceptible to infection through vaccination or natural infection. The original rates of transition were set to approximate the outbreak of 1983-84.

Economic Model

The economic model is an application of economic welfare analysis. Economic welfare analysis evaluates how market prices and quantities adjust to changes in disease control measures. It also measures the effects of disease spread, and how consumers and producers are affected by the adjustments in market prices and quantities. The effects on consumers and producers are measured in terms of changes in the difference between what consumers are willing to pay and what they actually pay for products (consumer surplus), plus returns to producer's fixed factors of production (producer surplus).

For the purpose of this analysis, impact on domestic production was measured in terms of the number of eggs lost due to disease or depopulation. The analysis examines economic impacts under high and nonpathogenic scenarios, and the different

control options. Output from the disease-spread model was used to help estimate the number of eggs lost.

Export losses were measured in terms of a single aggregate poultry meat. Therefore, the estimated consumer benefit may be somewhat overstated due to differences in consumer preferences for products consumed domestically versus those intended for export. Modeling the differences in consumer preferences is beyond the scope of this analysis.

Estimates of regionalized export losses were based on the proportion of total broiler production in each state. This proportion was applied to estimates of the US impact if poultry meat exports were eliminated entirely. If a regionalization strategy is implemented, multi-state poultry companies may be able to alter their distribution channels, minimizing the adverse effects of export restrictions in a given region. The level to which these adverse effects could be minimized is unknown at this time. If an acceptable regionalization strategy cannot be established, the full impact of any export bans would be felt.

Disease Control Scenarios

Several scenarios were developed in order to examine the cost-benefit of alternative control options. The scenarios were evaluated using computer simulation models described above. The scenarios were modeled over a 21-week period, starting with one infected flock. The following is a description of each scenario and assumptions.

1. Voluntary Control or "Do Nothing" Approach

After consulting with the Pennsylvania Department of Agriculture,we considered the "do nothing" approach an infeasible option. We did not model its impacts. The main reason was if, in 1997, PDA had not imposed quarantines and restricted poultry and poultry product movement, spread of infection could have been substantial. Other reasons are discussed below.

- This scenario would assume that neither State nor Federal authorities will take any steps to contain or control the situation. A similar approach was implemented in 1983, before the virus became highly pathogenic. Some industry members will voluntarily increase their level of biosecurity, others will not. Even if most of the industry increased their biosecurity practices, it would take only a few breaches in this effort to allow the virus to spread. Because of the traffic in feed, feed ingredients, service personnel, maintenance personnel, vaccination, placement, and catch crews, etc., infection among flocks could be expected to rapidly spread within the state.

- Without local control, AI would likely be transported out of the state into surrounding areas. Large poultry producing states nearest Pennsylvania, specifically the Delaware, Maryland, Virginia (Delmarva) region, would likely be

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Disease Control Scenarios
Several scenarios were developed in order to examine the cost-benefit of alternative control options. The scenarios were evaluated using computer simulation models described above. The scenarios were modeled over a 10-year period, starting with one infected flock. The following is a description of each scenario and assumptions.

1. Voluntary Control or "Do Nothing" Approach
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- This scenario would assume that neither State nor Federal authorities will take any steps to contain or control the outbreak. A similar approach was implemented in 1983, before the virus became highly pathogenic. Some industry members will without any increase their level of biosecurity, others will not. Even if none of the industry increased their biosecurity practices, it would take only a few breaches in the [illegible] of where the virus to spread. Because of the traffic in feed, feed ingredients, service personnel, maintenance personnel, vaccination, placement, and used manure, etc., [illegible], the virus would be expected to rapidly spread within the state.

- Without local control, AI would likely be transmitted out of the state into surrounding areas. Large poultry producing states around Pennsylvania, specifically the Delaware, Maryland, Virginia (Delmarva) region, would likely be

the first areas affected. We understand that, some of the layer flocks in Maryland shared common feed company sources and vaccination crews with the currently affected area in Pennsylvania. Feed and feed ingredient trucks serving flocks within the current quarantine area also served broiler flocks on the Delmarva region, before the area quarantine. The estimated value of the broiler and support industries on the Delmarva is $1.5 billion dollars. Pennsylvania's poultry industry is valued at $563.5 million. Virginia produces $773 million of poultry and poultry products yearly and many of their producers have direct ties and traffic with North Carolina.

- If Pennsylvania did not quarantine the affected area, neighboring states may impose embargoes on poultry and poultry products moving from Pennsylvania. Placement of embargoes might send an attention-getting message to our international trading partners potentially resulting in trade restrictions.

- Producers lack the authority to impose and enforce quarantine zones and movement controls. When nonpathogenic avian influenza was identified in commercial layer flocks in Lancaster County, the industry requested that a quarantine be placed around an area approximating a 5-mile radius from the first positive flock. In 1983-84 and during the current situation, the PDA was able to enlist the Pennsylvania State Police to enforce the quarantine zone. Establishment of this quarantine zone provides reassurance to surrounding states and industry.

2. Depopulation Scenario

For this scenario, flocks were moved from the infectious to the depopulated or removed state after 1 week. This assumption was based on experience in the 1983-84 outbreak when active surveillance was devised to sample flocks on a weekly basis. In 1983, flock owners were instructed to place recently dead birds in containers near the road. State or Federal personnel collected tracheal and cloacal swabs from these birds. The swabs were tested for evidence of virus. Collection personnel established a daily route allowing them to cover a large area while sampling many flocks. The routine was repeated the following week, providing a weekly test record for each flock in the quarantine zone (referred to as "dead bird pickup"). Upon detection of infection in a flock, a quarantine was implemented immediately to prevent movement of the virus off the premises. Thus, from the time a flock entered the infectious state until quarantine was generally not more than one week.

In 1983-84 the offer of indemnity payment also encouraged owners to report illness as early as possible. Producers were paid only for the live birds on the premises at the time of field diagnosis and quarantine. With the highly pathogenic AI virus it would not be uncommon for an owner to experience several thousands of bird deaths in a matter of a day. The owner could expect no compensation for losses that occurred prior to the quarantine and diagnosis. This encouraged early reporting since that would provide maximum compensation from the authorities. If the flock owner did not

contact authorities, dead bird pickup would likely identify the infected flock within a 7 day window. We assumed that placement of the quarantine effectively removes the flock from infected status and places it into the immune status where it no longer poses a risk for other susceptible flocks.

In 1983-84, an infected flock was quarantined at the time of field diagnosis. Soon after that, birds were destroyed. After depopulation there was an obligatory downtime where the premises was cleaned and disinfected. Flock houses were sampled and must have tested negative on two tests, a minimum of 30 days apart, before restocking. The final laboratory report releasing the premises from quarantine took a minimum of 14 days after the last sampling. At this time the premises was eligible for restocking with new, susceptible egg laying chickens.

Considering the above, we assumed it would require a minimum of 45 days to complete the necessary testing to reach the point of repopulation. Therefore, theoretical repopulation of flocks occurred 7 weeks after diagnosis. Also, because of the imperfections of the laboratory tests and the necessary downtime for removing manure, repairing the caging and electrical systems within a house, etc., it was further assumed that only 10% of the potentially eligible houses would be repopulated after 7 weeks. Beginning in the eighth week, 10% of the houses found infected in Week 1 moved to the susceptible category. In the ninth week, 10% of the flocks diagnosed in weeks 1 and 2 were repopulated and moved into the susceptible category.

3. Quarantine and Containment of Infected Flocks

We assumed that positive commercial flocks are detected fairly quickly with the “dead bird pick- up” procedure discussed above. The average time the birds were infected and remained infectious was again assumed to be 1 week. In this scenario, some flocks would become naturally infected and remain immune for life. The time in immune state was set at 52 weeks, meaning they do not reenter the susceptible state through the duration of the simulated outbreak.

Flocks infected with highly pathogenic avian influenza in 1983-84 lost their table egg market since the eggs were destroyed along with the birds during the depopulation. Flocks infected in the current nonpathogenic avian influenza outbreak may similarly experience production (morbidity and mortality) losses. Under the plan currently in place in Pennsylvania, eggs from infected flocks are diverted to an instate pasteurization plant. Infected flocks were released from quarantine when the flock was no longer exhibiting clinical signs and was negative on two tests (30 days apart for avian influenza). Flock owners are then permitted to reenter the table egg market and therefore, infected flocks lose their table egg market only for short period. However, if this pasteurization market becomes saturated, flock owners may be unable to recoup any salvage value for their eggs, significantly increasing their cost.

4. Vaccination with Quarantine

Research has shown that clinical signs and production losses can be mitigated by use of vaccine. However, it also shows that vaccinated birds can become infected with field strain virus. Vaccinated birds can be expected to shed less virus, not develop as severe clinical signs, and not experience the production losses that unvaccinated, birds will. Some of the literature note a 1-2 log-factor decrease in the amount of virus shed by experimentally challenged vaccinated birds.

The vaccination scenario was simulated by vaccinating 60 flocks (assuming 70,000 birds per flock) over the initial 4-week period. This is approximately the number of flocks capable of being vaccinated once with 4 million doses of vaccine, ordered by PDA.

The key parameter for vaccine use is its efficacy in reducing flock-to-flock transmission of field virus. We are not aware of any research or data on this topic. In the absence of this information, and for example purposes, we simulated four levels of vaccine efficacy: 0%, 25%, 50% and 75%. These levels were implemented in the model by starting with varying number of flocks in the immune state, assuming that one million birds per week will be vaccinated. For example, the 75% effective scenario starts with 45 (60 X 0.75) flocks in the immune state during the first 4 weeks of the simulation.

In Pennsylvania, there is a current proposal to place unvaccinated, sentinel chickens in vaccinated flocks. These sentinel birds will be tested regularly to determine if field strain virus has entered the flock. If there is evidence of infection the flock will be treated as an infected flock. When a vaccinated flock is found infected with field strain virus, it will be managed as any other infected flock. Eggs will be diverted to pasteurization, if there is market available. Therefore, we modeled the economic impacts with and without total loss of table and pasteurization egg markets.

Vaccinated flocks or naturally infected were assumed to be immune for the remaining flock life. We assumed quarantine was effective in reducing flock spread and set the model for only one week waiting time in the infectious state, to match the other scenarios.

RESULTS

The simulated number of infected flocks and economic impact of “quarantine only” compared to “quarantine with depopulation” are shown in Table 1 for highly pathogenic and nonpathogenic AI. Figure 1 shows the course the simulated epidemics compared to the actual for 1983-84. The morbidity and mortality (M&M) impacts for the nonpathogenic scenarios are based on data provided by PDA for the current outbreak. For nonpathogenic AI, the economic losses are shown with and without total loss of table and pasteurization egg markets. For the quarantine and vaccination scenarios, any morbidity and mortality occurring during the time of flock quarantine was included in the market loss calculation.

The simulated number of infected flocks and economic impact of vaccine for hypothetical efficacy is shown in Table 2. Economic losses are reported with and without total loss of all egg markets.

Table 3 shows the projected annual export losses if Pennsylvania vaccinates for AI, or the virus converts to highly pathogenic form. Four different potential regionalization scenarios are shown. For the purpose of this evaluation, the estimated impacts of these scenarios was based on the total impact to the US due to a complete loss of poultry meat exports weighted by the proportion of broiler production occurring in each region. Note that these losses are on an annual basis and export restrictions are expected to last more than one year.

Figure 1. Avian Influenza. Simulated epidemic curves for Quarantine and Depopulation and 1983-84 outbreak

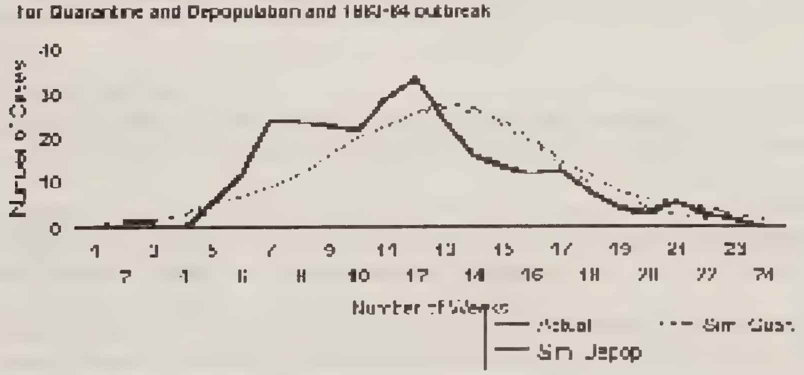

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Table 1: Simulated number of avian influenza infected flocks & economic impact of quarantine and depopulation control options in Pennsylvania layer flocks
(N = 468 at risk flocks (>3,200 birds) in the 1983-84 quarantine zone)

	Quarantine only	**Depopulation and quarantine**
Time in Infectious State	1 week[b,c]	1 week[b,c]
Time in Immune State	52 weeks	7 weeks, 10% exit each week after
Number infected flocks	262	281
LOSSES for HIGH PATH. ($ millions)		
Producer Loss	$17.2 **plus** export impacts[d]	$27.2 **plus** export impacts[d]
Consumer Loss	$55.6 **plus** export impacts[d]	$89.6 **plus** export impacts[d]
Net Loss	$72.8[e] **plus** export impacts[d]	$117.4[e] **plus** export impacts[d]
LOSSES NON PATH ($ millions)	M&M [f]/ M&M plus Market Loss[g]	
Producer Loss	$4.0 / $17.2	$27.2
Consumer Loss	$13.1 / $55.6	$89.6
Net Loss ($)	$17.1 / 72.8[e]	$117.4[e]

[a] Under the depopulation option, incidence rate and number of flocks infected were based on the 1983-84 Pennsylvania outbreak.

[b] Assumes early detection procedures

[c] Assumes 100 percent effectiveness of flock quarantine in reducing virus spread.

[d] Expected export losses result from conversion to High Path. See impacts in Table 3 for various regionalization scenarios.

[e] Government costs were not included as they are similar for both scenarios, with the exception of indemnity, which is a transfer cost from government to industry. Detailed data is available from the authors.

[f] M&M = Morbidity and mortality. Based on mortality and egg losses for the 1997 virus reported by the Pennsylvania Department of Agriculture.

[g] Market loss due to infection with field virus and loss of table and pasteurization egg market, if pasteurization market is saturated. Under current conditions, it is estimated that approximately $3.4 million of the market losses shown could be salvaged/regained in the pasteurization market.

Table 2. Simulated number of infected flocks & economic impact (excluding export losses) of avian influenza vaccine use with different assumed efficacies for reducing flock-to-flock spread[a].

Vaccine Efficacy [b]	**zero**	**25%**	**50%**	**75%**
Infected flocks	262	236	210	184
LOSSES ($ millions)	M&M[c] / M&M including Market Loss[d]	M&M[c] / M&M including Market Loss[d]	M&M[c] / M&M including Market Loss[d]	M&M[c] / M&M including Market Loss[d]
Producer Loss[e]	$1.4 / $17.2	$1.3 / $15.7	$1.3 / $13.5	$1.3 / $12.0
Consumer Loss	$1.2 / $55.6	$1.1 / $50.8	$1.0 / $43.6	$0.8 / $38.7
Net Loss	$2.6 / $72.8	$2.4 / $66.5	$2.3 / $57.0	$2.1 / $50.7

[a] Export losses could result from use of vaccine and must be added to all scenarios. See impacts in Table 3 for various regionalization scenarios.
[b] Assumes 60 flocks (70,000 birds/flock) started in immune state during first 4 weeks of outbreak. Efficacy refers to reducing flock-to-flock spread, not clinical signs.
[c] M&M = Morbidity and mortality. Based on mortality and egg losses for the 1997 virus reported by the Pennsylvania Department of Agriculture.
[d] Market loss due to infection with field virus and loss of table and pasteurization egg market, if pasteurization market becomes saturated. Under current conditions, it is estimated that approximately $3.4 million of the market losses shown could be salvaged/regained in the pasteurization market.
[e] Includes production losses due to handling of birds and costs of vaccine administration (4 million birds vaccinated twice @ $0.12 each = $1 million); plus about 2 days of low level production losses under the nonpathogenic scenario.

Table 3: Projected Annual[a] Export Losses if Pennsylvania Uses AI Vaccination or the Virus Converts to Highly Pathogenic Under Four Potential Regionalization Scenarios
($ millions)

	Pennsylvania (PA) only	PA + Delmarva	PA + Delmarva + Southeast USA	PA + Delmarva + Southeast USA Rest of USA
Producer Loss[b]	21.5	166.5	863.5	1300
Consumer Gain	19.4	154	799	1200
Net Loss	1.6	12.4	64.4	96.7

[a] Annual export losses shown above should be multiplied by the number of years trade sanctions would remain in place, probably between 2 and 3 years.
[b] These losses were based on proportion of all poultry meat production that come from respective regions. It is likely that should PA be embargoed production from other states can be shifted to fill that market, decreasing the loss.

DISCUSSION

This analysis focused on the disease production impacts in commercial layer operations, as well as potential impacts in the export markets for US poultry meat. We looked for benefit of vaccine use in three areas: 1) reducing producer losses, 2) decreasing the likelihood of conversion to highly pathogenic virus, and 3) decreasing the number of number of infected flocks. Compared to the high cost of potential export market loss, the benefits appear minimal.

The efficacy of vaccine at reducing flock-to-flock spread is the key variable affecting the outcome of this analysis. No data were available on this topic. However, there is agreement in the literature and expert opinion that vaccination will not prevent the circulation of field virus among flocks. Vaccination will reduce the amount of virus shed from field strain infected birds. The impact of this reduction, on the probability of flock-to-flock spread, is expected to be slight because of the large amount of virus excreted by 70,000 vaccinated birds.

We had planned to model the likelihood of the virus converting from nonpathogenic to highly pathogenic. Instead we estimated economic impacts for high and nonpathogenic scenarios without assigning probabilities. We could find no data applicable to bird or flock level conversion probabilities. If vaccination decreases the number of birds infected, it may decrease the number of opportunities for random molecular changes in the virus. The mechanism that triggers conversion is currently unknown. Also, experts generally feel that the H7N2 virus in Pennsylvania is stable and unlikely to convert to a highly pathogenic strain. This opinion suggests that vaccine use would have little impact on the emergence of highly pathogenic AI.

The time a flock spends in the infectious state is a critical variable as it affects the number of flocks that can spread disease at any one time. According to field experience and expert opinion, flocks stay infectious for an average of 4 weeks. However, the time flocks spend in the infectious state was set to 1 week for all scenarios. This assumption allows us to examine the impact of depopulation and vaccine efficacy without an added variable. It is equivalent to that quarantine, once implemented, is fully effective in all scenarios.

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